Fast-ion studies with three-ion ICRF scenarios in non-active JET plasmas

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Significant progress with the development of three-ion ICRF scenarios in support of the ITER Research Plan has been recently achieved [1]. We report the results of JET studies where the three-ion ^{4}He-(^{3}He)-H scheme was applied for heating non-active H-^{4}He plasmas, both on-axis and off-axis [2], and studying the impact of fast ions on the plasma confinement. The spatial profile of energetic ^{3}He ions was controlled by varying the ICRF antenna phasing, resulting in significant differences in MHD behaviour and sawtooth dynamics. Our results confirm that the three-ion ICRF scenario can be applied to control the radial profile of the safety factor and sustain plasmas with an inverted *q*-profile at JET, complementing earlier observations of its application in D-^{3}He plasmas [3]. Another important highlight of the JET experiments in H-^{4}He plasmas reported here is the demonstration of the capability to measure simultaneously both He isotopes, $n(^{4}\mathrm{He})/n_e \approx$ 5-15% and $n(^{3}\mathrm{He})/n_e \approx 0.2\%$, using the high-resolution sub-divertor gas spectroscopy [4].

In this contribution, we also report on the successful application of the three-ion ^{9}Be/^{22}Ne/Ar-(^{4}He)-H ICRF scheme at JET. This scenario makes use of intrinsic ^{9}Be ($Z/A \approx 0.44$), and/or extrinsic impurities with a similar charge-to-mass ratio, e.g., ^{22}Ne and Ar ($Z/A \approx 0.45$), to optimize the efficiency of ICRF absorption by a small amount of ^{4}He ions ($n(^{4}\mathrm{He})/n_e \approx 0.5\%$) in hydrogen plasmas [1]. JET experimental results confirm that an additional injection of a very small amount of ^{22}Ne impurities is beneficial for maximizing the population of MeV-range ^{4}He ions with ICRF in the plasma, as evidenced by gamma-ray spectroscopy [5]. In the absence of a direct control of the level of ^{9}Be impurities, an additional seeding of ^{22}Ne or Ar impurities is a promising technique that can be also applied in future ITER plasmas.

[1] Ye.O. Kazakov et al., *Phys. Plasmas* **28**, 020501 (2021)
[2] M. Schneider et al., *EPJ Web. Conf.* **157**, 03046 (2017)
[3] M. Dreval et al., *Nucl. Fusion* (2022); https://doi.org/10.1088/1741-4326/ac45a4
[4] S. Vartanian et al., *Fusion Eng. Design* **170**, 112511 (2021)
[5] M. Nocente et al., *Plasma Phys. Control. Fusion* **62**, 014015 (2020)